National Aeronautics and Space Administration

climate risks

Adapting Now to a Changing Climate

Stennis Space Center

the issue

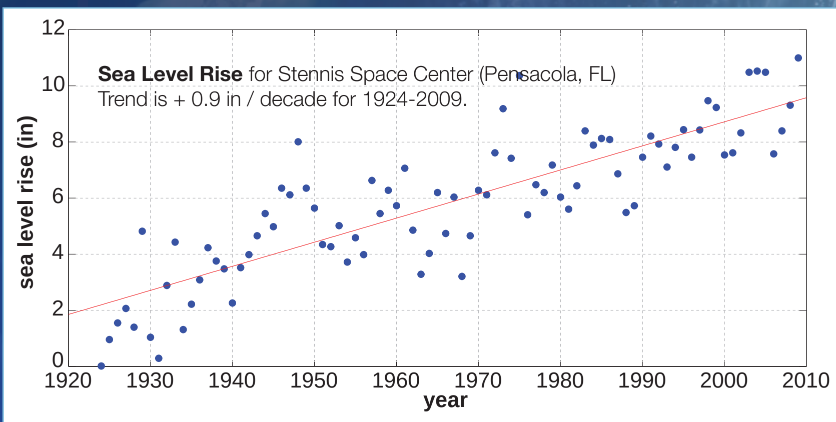
Over a century of Stennis Space Center area climate data show a pattern of sea level and temperature rise. Data from Waveland, Mississippi indicate that the average annual temperature has risen approximately 1.3 degrees over the past century. Data from Pensacola, Florida, another area on the Gulf of Mexico comparable to the Stennis area, show that sea level has risen over 7 inches during the past 75 years.

Using climate models, scientists project continued sea level rise and warmer temperatures in the region. Along with sea level rise, storm surges from hurricanes may increasingly make natural and built systems vulnerable to disruption or damage. Government agencies and other organizations, including utilities, planning commissions, and research institutions are currently assessing the potential of climate hazards to affect the region and their operations.

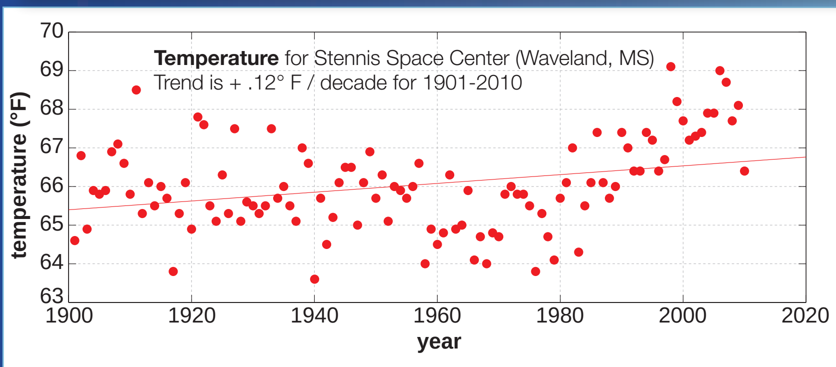
This handout can help area leaders (NASA together with its tenants, neighbors, and area partners) understand what they may expect in the future, and plan accordingly.

What's already happened *locally?*

<ins>Sea Level</ins> has risen over decades, though individual years vary somewhat



<ins>Temperature</ins> has risen too, but the trend varies more year-to-year



A century of local data tells us <ins>the climate is changing.</ins>

the setting

NASA Stennis Space Center occupies a nearly circular area of approximately 32.5 square miles (about 21,000 acres) in western Hancock County, MS. An additional buffer area of about 180 square miles (roughly 117,000 acres) surrounds Stennis. The Center is about 49 miles northeast of New Orleans and about 50 miles west of Biloxi, MS. The East Pearl River flows along the southwest boundary of Stennis and connects to the canal system that flows through the test stand area.

what's at stake?

Stennis Space Center (SSC) is the nation's largest rocket engine test facility. Its professionals conduct rocket propulsion testing for NASA, the Department of Defense (DoD), and the private sector. Considering direct and indirect impacts, Stennis supports more than 24,000 jobs, providing over $1.14B of personal income and retail sales of $686M.[1] In addition, the presence of Stennis results in about $122M of local tax revenues. Approximately 5,400 people work within the Center; this includes 2,125 NASA civil servants and contractors, 2,069 DoD civil servants and contractors, 232 Department of Commerce civil servants and contractors, and 932 employees in other resident agencies. SSC's facilities are conservatively valued at $2.6B.

Three major test stand complexes (A, B, and E) serve the primary mission at SSC - rocket propulsion testing. A new test stand (A-3), will be operational in 2013 to simulate high-altitude operation of engines traveling to deep space. SSC occupies over 21,000 acres; a large buffer zone surrounds the Center. A 7.5 mile canal waterway supports the transportation of liquid propellants, rocket engines, and engine components. Other facilities support test control, data acquisition, high-pressure gas storage, electrical generation, and high-pressure industrial water service, with a 66-million gallon reservoir.

Stennis professionals also apply expertise in remote sensing, oceanography, land use/land cover analysis, signal processing, electronics, and mathematical modeling to conduct research and create new tools and methods to monitor the environment. Earth science research enables response to crises (e.g., hurricanes, oil spills), and supports sustainability policies and other societal issues.

Natural resources at SSC provide value as well. Much of the SSC property and buffer zone is considered jurisdictional wetlands by the Army Corps of Engineers. The buffer zone supports timber production, sand and gravel mining, and recreational hunting and fishing. The four plant communities in the area include pine flatwoods, bottomland hardwood, pitcher plant bogs and swamp, and grasslands and marshes. These habitats host over 100 bird species, 20 frog species, 14 snake species and the alligator, and 26 mammal species.

[1] All figures in this paragraph are from NASA's John C. Stennis Space Center – Mission Brochure, 2012

projected changes

The Climate Science Context

Scientists have collected weather and climate data and indicators of longer-term climate patterns (such as ice cores and tree rings) from the entire globe. Based on analyses of these data, plus a growing understanding of physical processes that control climate, scientists have developed sophisticated models that project future climate changes. Many climate models project that climate change will accelerate this century. The US Global Climate Research Program's report summarizes these results at http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts. NASA climate scientists are an important part of the international research effort. NASA is a key player in modeling climate variables and collecting both earth-based and space-based data used to develop and validate climate models and identify climate impacts.

Climate Scenarios

The United Nations Intergovernmental Panel on Climate Change (IPCC) developed several greenhouse gas (GHG) emissions scenarios based on differing sets of assumptions about future economic growth, population growth, fossil fuel use, and other factors. The emissions scenarios range from "business-as-usual" (i.e., minimal change in the current emissions trends) to more progressive (i.e., international leaders implement aggressive emissions reductions policies). Each of these scenarios leads to a corresponding GHG concentration, which is then used in climate models to examine how the climate may react to varying levels of GHGs. Climate researchers use many global climate models to assess the potential changes in climate due to increased GHGs. In this case, 3 emissions scenarios were used in 16 different global climate models, to provide a range of possible outcomes and provide a sound basis for policy decisions and adaptation planning.

Stennis Area Climate and Weather Today

The climate at Stennis Space Center and its surrounding region is classified as humid subtropical. Average temperatures in the area range from around 49°F in January to about 82°F in July. Annual precipitation is about 64 inches and precipitation is relatively evenly distributed throughout the year. Local weather hazards that affect the center include hurricanes and thunderstorms. Several hurricanes affected Stennis operations in recent history – Betsy in 1965, Camille in 1969, and Katrina in 2005.

Future Climate Projections

Based on local temperature and sea level records, scientists from NASA's Goddard Institute for Space Studies adjusted regional climate models to make projections more specific and useful for Stennis. This "downscaling" process can provide a more precise projection for a specific location (in this

What can we expect locally?

	2020's	2050's	2080's
Average Annual Precipitation	-5% to +5%	-10% to +5%	-10% to +5%
Sea Level (inches)	+2 to +4	+6 to +10	+11 to +19
Sea Level–Rapid Ice Melt Possibility (inches)	+4 to +8	+18 to +27	+41 to +55
Average Annual Temperature (F°)	+1.5° to +2.0°	+2.5° to +4.5°	+3.5° to +7.0°

Average sea levels and temperatures are expected to rise.

Temperature and precipitation projections reflect a 30-year average centered on the specified decade; sea levels are averages for the specific decade. Data for 1971-2000 from Waveland and Poplarville, MS provide a baseline for Temperature (66.5°F) and for Annual Precipitation (64.3 inches). Sea level data are for Waveland. Temperatures are rounded to the nearest half degree, precipitation projections to the nearest 5%, and sea level rise to the nearest inch. Shown are the central range (middle 67% of values) across the GCMs and GHG emissions scenarios. Data are from the NOAA National Climatic Data Center.

case, the Stennis Space Center area) than modeling for an entire region, such as the southern US. Using these models, scientists project higher average annual temperatures and rising average sea levels for the Stennis area. While little change is expected in average annual precipitation, storms may be more intense, leading to increased risks of flooding.

The Case for Adaptation

Because of its location on the Gulf Coast, sea level rise and storm surge may be the biggest threats to SSC. The area has always been subject to hurricanes, and the associated high winds and flooding. The combination of rising sea level and severe storms could produce catastrophic impacts on SSC and the surrounding high profile infrastructure assets, human capital, and natural resources. Land subsidence in the area worsens the impacts of rising seas and storm surges. Projected changes in the frequency of some extreme events like hot and cold days (see tables below) may also lead to large impacts. Most people are likely to notice the impacts of extreme events – more heat waves, more downpours, more flooding – rather than the gradual rise in average annual temperatures and sea levels. The Center's future is intricately connected with broader social, economic, and environmental trends expected throughout the region, so SSC stewards developing adaptation strategies will also need to work together with regional decision-makers on the Gulf Coast.

A Note on Interpreting Climate Projections

Model projections suggest a significant and progressive long-term warming trend for the Stennis area, but they cannot provide an exact temperature for a future date. For example, while it is inappropriate to assert that the average temperature at SSC will be 70.0°F in 2043, it is appropriate to say that between 2040 and 2070, temperatures may increase 2.5 to 4.5 degrees above the average baseline temperature.

Rapid Melting of Land-Based Ice

Data collected over the past several years reveal that land-based ice, such as that on Greenland or the Western Antarctic Ice Sheet, is melting faster than most Global Climate Models project. Because this could change sea levels substantially, climate scientists developed an alternative model component that incorporates observed and longer-term historical land-based ice melt rates. This rapid ice melt approach suggests that sea levels could rise three times as fast, adding several feet along the nearby coast by the 2080s. (see Rapid Ice Melt data in the Climate Variables chart to the left.)

Daily Temperatures	Baseline	2020s	2050s	2080s
Days/year **at or above 100°F**	2	3 to 6	6 to 20	10 to 50
Days/year **at or above 90°F**	82	93 to 106	106 to 131	120 to 155
Days/year **at or below 40°F**	62	49 to 54	40 to 50	31 to 45
Days/year **at or below 32°F**	25	16 to 20	12 to 17	8 to 14

Baseline is from Poplarville, MS

Qualitative Changes in Extreme Events During This Century

Event	Direction of Change	Likelihood
Hot Days	↑	Very Likely
Intense Precipitation	↑	Likely
River Flooding	↑	Likely
Drought	↑	More likely than not
Intense Winds	↑	More likely than not

Based on global climate model simulations, published literature, and expert judgment

Hot and Cold Day Projections

The number of days per year exceeding 90˚F is projected to rise dramatically in the coming century, and the number of days with temperatures below 40˚F is projected to decrease. More hot days would affect outside work, energy use, agricultural practices, and habitats.

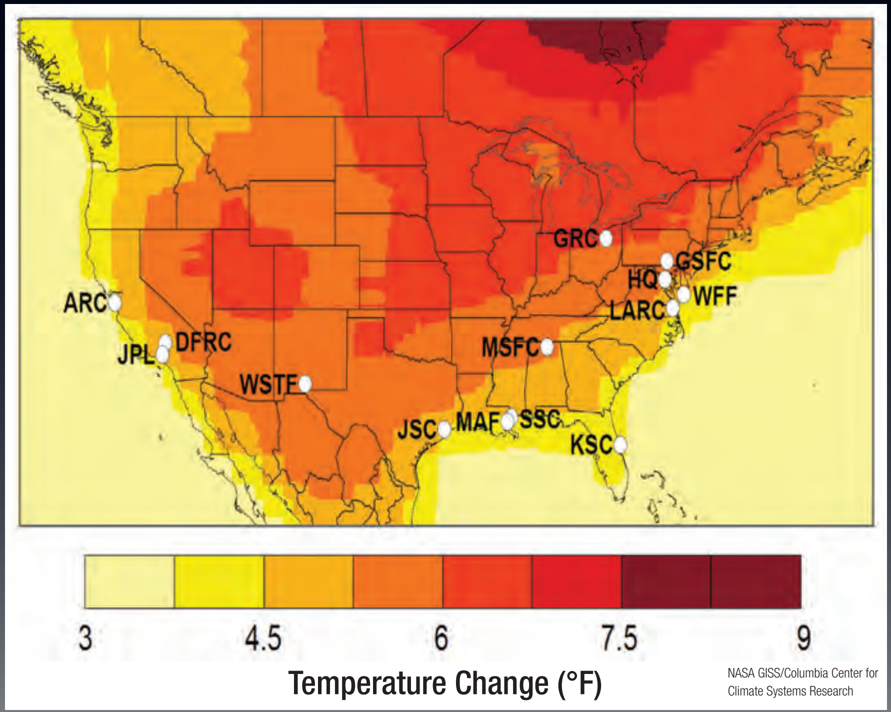
our responsibility

The time to develop and implement adaptation strategies is now. Executive Order 13514 directs federal agencies to assess and manage the effects of climate variables on operations and mission in both the short and long term. A changing climate in the Stennis area will affect facility operations (e.g., water and energy management), natural resources (e.g., new invasive species control), infrastructure that is vital to mission success (e.g., increased protection against flooding), quality of life in the community (e.g., additional heat stress management), and the regions' economy (e.g., increased public expenditures on utilities). By considering these impacts during existing planning and decision-making cycles at Stennis Space Center, impacts to their missions may be abated or reduced. Recent construction initiatives at SSC in the wake of Hurricane Katrina provide examples of adaptation measures (e.g. stronger high pressure gas facility, stronger bulk diesel storage area) that take the increasing risks of climate impacts into account. Adaptation strategies developed for the Center may also prove beneficial to the local community as planners implement short-term tactical changes now, while simultaneously planning for longer-term strategic adaptation measures. Some potential impacts are listed in the chart below.

The new Emergency Operations Center built after Hurricane Katrina in 2005 demonstrates SSC's commitment to a climate-resilient future.

Climate Trends	Potential Impacts
Rising Sea Level	Exacerbated flooding from storm surges; reduced emergency response capabilities. Increased salinity impacts to drinking water resources and habitats
Increased Coastal Flooding	Impacts to wastewater treatment plants on the coast; damage to infrastructure; changes in shoreline habitats; overloading of stormwater management system
Overall Increased Temperature	Increased cooling costs in the summer; decreased heating costs in the winter. Changes in plant and animal cycles, including pest and disease vector species
Increased Number of High Temperature Days	Potential for damage to infrastructure materials; potential for limiting work and recreation outdoors; increased health problems related to heat stress
Precipitation Changes	Increased flooding from extreme precipitation events; increased risk of drought as temperatures rise; habitats affected by fluctuating groundwater levels

Projected Temperature Change (°F), 2080s minus 1980s, A1B Emissions Scenario*



*Average projected temperature change across sixteen global climate models for the A1B emissions scenario. The A1B scenario, one of several developed by the IPCC, assumes high CO2 levels for first the half of the 21st century, followed by a gradual decrease after 2050. Each time period (the 2080s and 1980s) reflects a 30-year average, not a specific point in time. ***The precise values shown in the map should not be interpreted as the most likely outcome.*** *The patterns of future climate change will depend on a range of factors, including the climate system, population, economics, technology, and policy.*

A Note about Downscaling Climate Data Specifically for Individual NASA Centers

The quantitative climate projections in this document are based on global climate model simulations conducted for the IPCC Fourth Assessment Report (2007) from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project Phase 3 (CMIP3) multi-model dataset. The simulations provide results from sixteen global climate models that were run using three emissions scenarios of future greenhouse gas concentrations. The outputs are statistically downscaled to 1/8 degree resolution (~12 km by 12 km) based on outputs from the bias-corrected (to accurately reflect observed climate data) and spatially-disaggregated climate projections derived from CMIP3 data. Results provide a more refined projection for a smaller geographic area. This information is maintained at: **http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections** and described by Maurer, et al. (2007)[1].

The **rapid ice melt scenario** and qualitative projections reflect a blend of climate model output, historical information, and expert knowledge. For more information about rapid ice melt models, see a paper and references at **http://www.nature.com/climate/2010/1004/pdf/climate.2010.29.pdf**.

Key Uncertainties Associated with Climate Projections

Climate projections and impacts, like other types of research about future conditions, are characterized by uncertainty. Climate projection uncertainties include but are not limited to:

1) Levels of future greenhouse gas concentrations and other radiatively important gases and aerosols,

2) Sensitivity of the climate system to greenhouse gas concentrations and other radiatively important gases and aerosols,

3) Climate variability, and

4) Changes in local physical processes (such as afternoon sea breezes) that are not captured by global climate models.

Even though precise quantitative climate projections at the local scale are characterized by uncertainties, the information provided here can guide resource stewards as they seek to identify and manage the risks and opportunities associated with climate variability/climate change and the assets in their care.

[1] *Maurer, E.P., L. Brekke, T. Pruitt, and P.B. Duffy (2007), 'Fine-resolution climate projections enhance regional climate change impact studies', Eos Trans. AGU, 88(47), 504.*

Authorization for NASA's climate risk management efforts, which began in 2005, includes:
- Federal Managers' Financial Integrity Act of 1982, supported by:
  - GAO (1999) Standards of Internal Control in the Federal Government
  - OMB Circular A-123 (2004) Management's Responsibility for Internal Control
- National Security Directive 51 and Homeland Security Presidential Directive 20: National Continuity Policy (9 May 2007) on localized acts of nature
- Presidential Policy Directive 8 – National Preparedness (30 March 2011) for catastrophic natural disasters
- Executive Order 13514 (8 October 2009) Leadership in Environmental, Energy and Economic Performance
- 2010 National Aeronautics and Space Act (51 USC Sec 20101 et seq)
- 2010 National Space Policy of the United States of America

Members of NASA's Climate Adaptation Science Investigator (CASI) Work Group contributed to this document.

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